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# (12) UK Patent Application (19) GB (11) 2 293 626 (13) A

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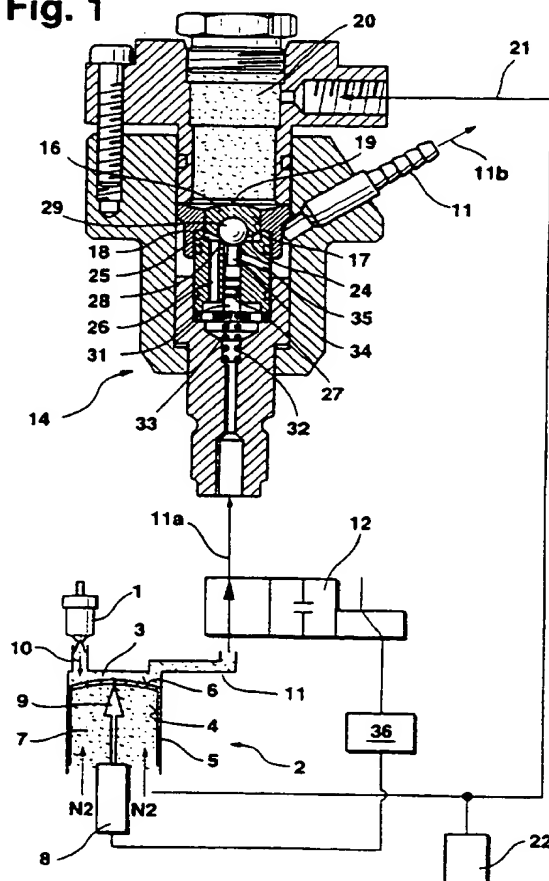
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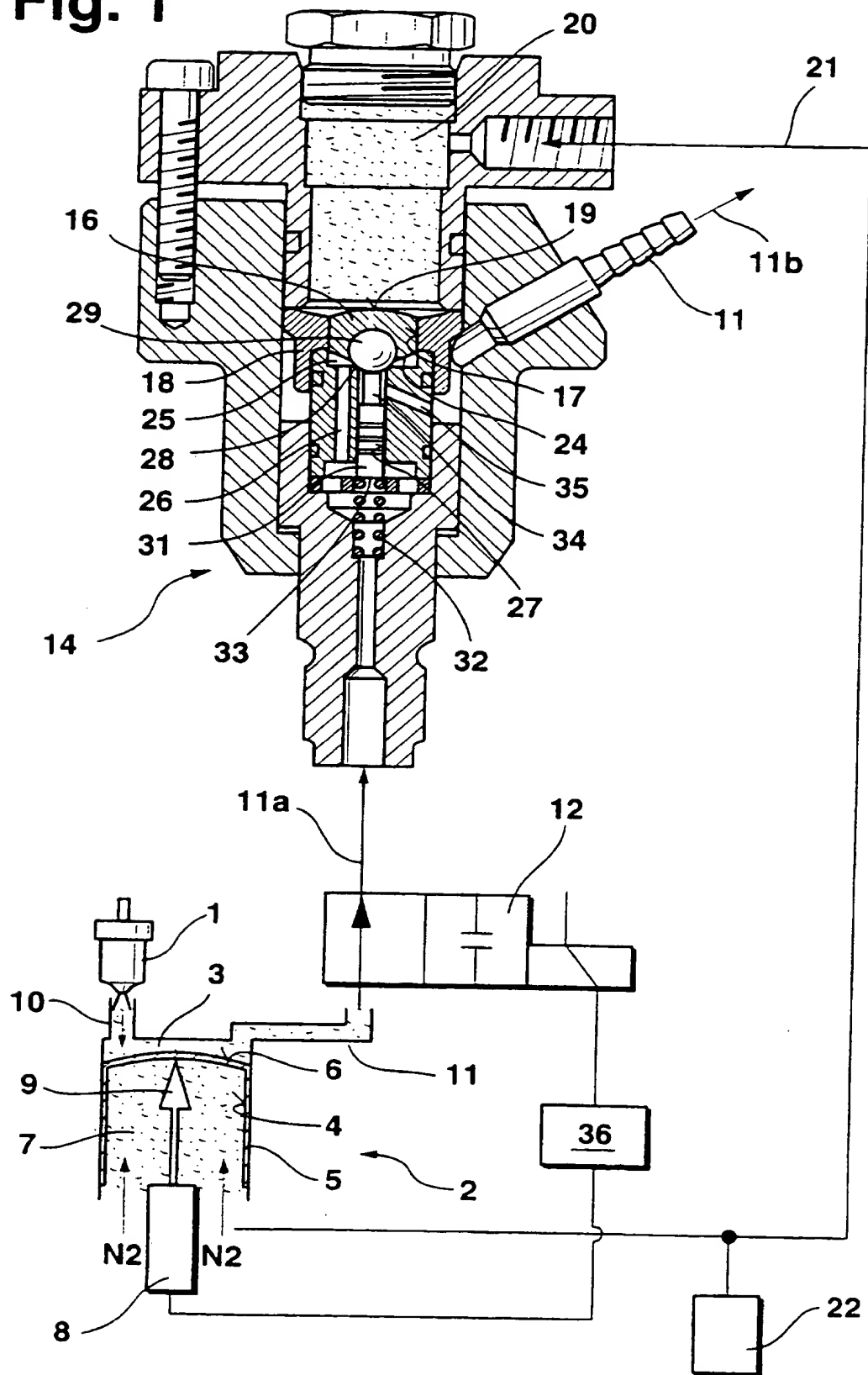
## (54) Measuring fuel injection

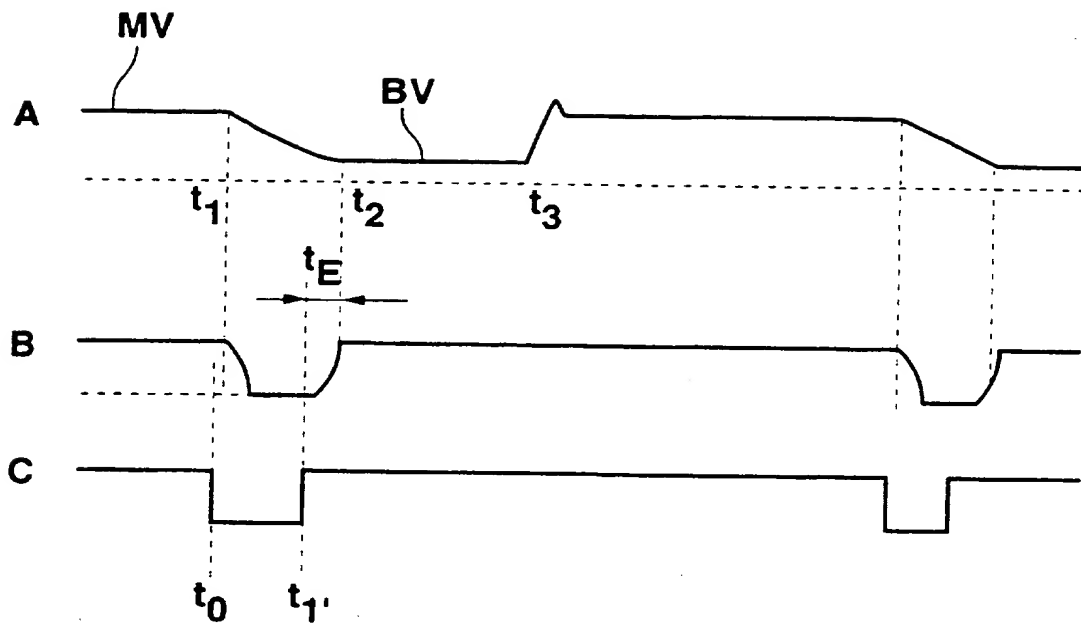
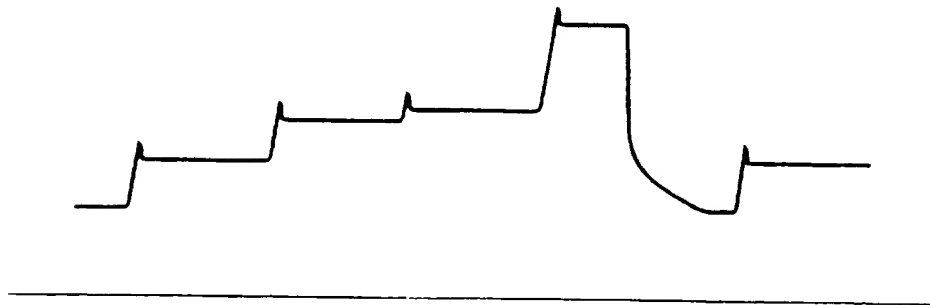
(57) Fuel injected into a chamber 3 displaces a piston 5 which is acted on by a constant nitrogen pressure. The displacement of the piston 5 is measured by means of a displacement sensor 8, 9. In order to provide a constant initial piston position, the piston is returned to its initial position at the end of measurement by the chamber 3 being relieved through a line 11 containing a solenoid valve 12 and a valve 14 providing a constant rate of fuel relief. The valve 12 receives a closing signal at a position of the piston 5, before the constant initial position, which provides compensation for the time taken for closure to occur. The valve 14 has a piston 16 or a diaphragm (116, Fig. 4) subject to nitrogen pressure in the chamber 20. A leakage annulus (47, Fig. 5) around the measuring piston (105) may be connected between the solenoid valve (112) and the valve 14.

Fig. 1



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**Fig. 1**

**Fig. 2****Fig. 3**

### Fig. 4

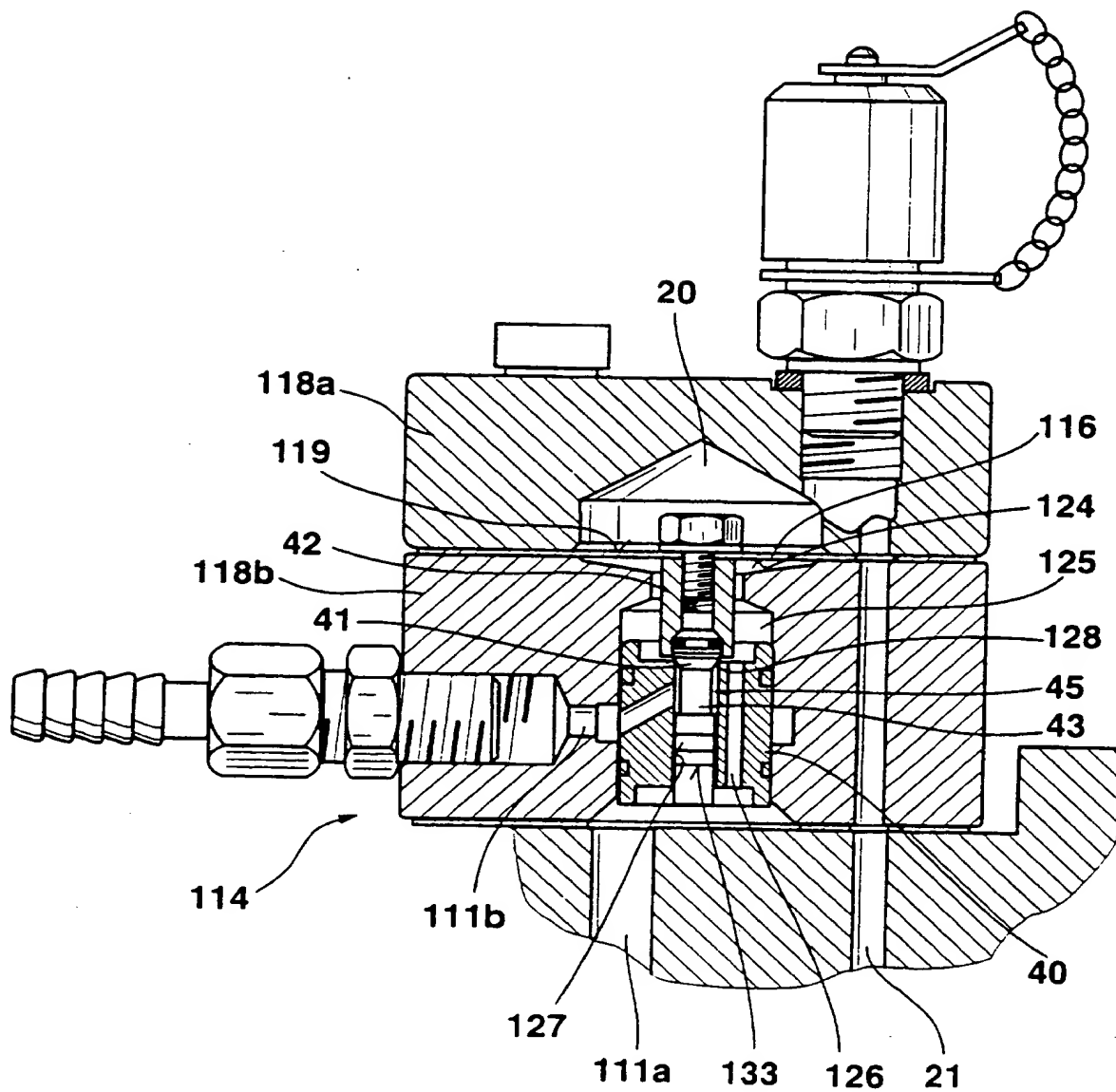
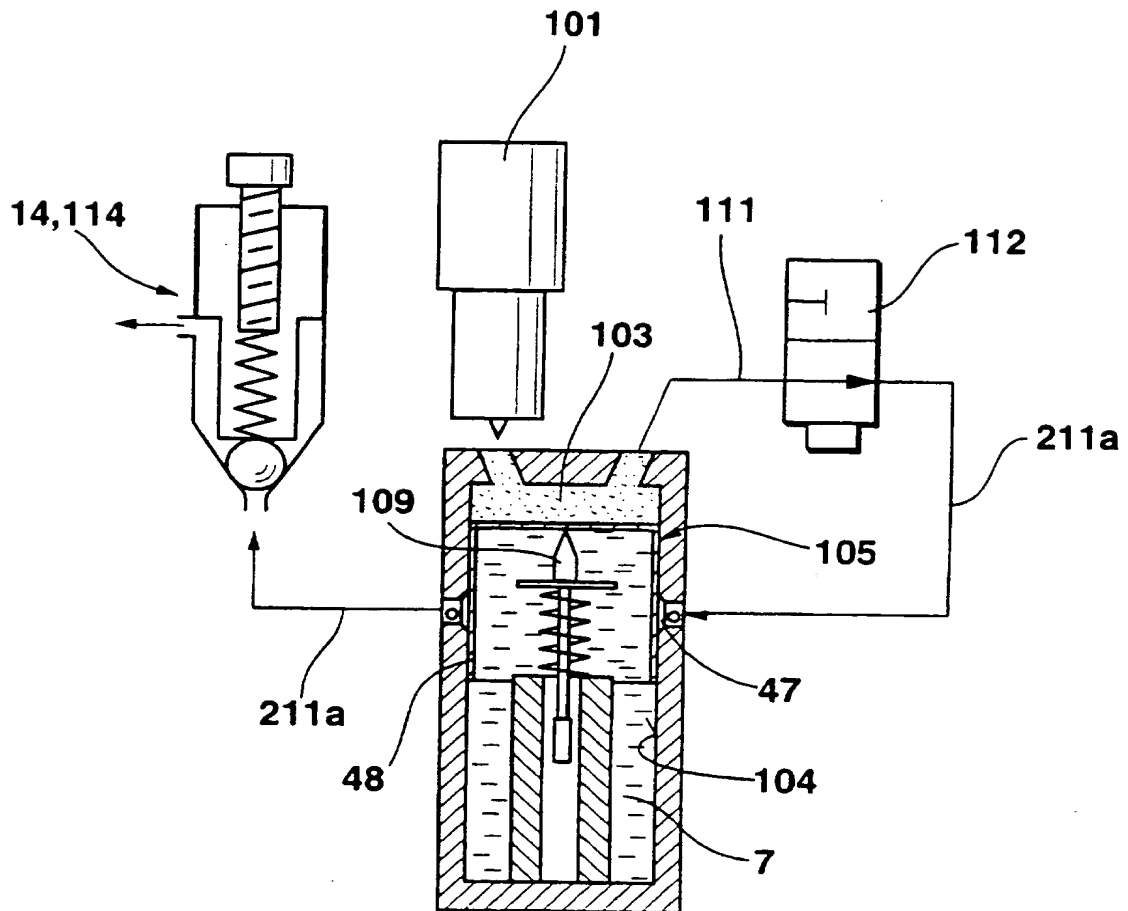


Fig. 5



Method and device for metering small quantities of  
fuel for injection

Prior art

The invention is based on a method and a device for metering small quantities of fuel for injection of the generic type of Patent Claims 1 and 4. In such a method, known from DE-A-39 16 419, and associated device, the switching delay of the controlled solenoid valve in the relief line is not taken into account during the resetting of the reference volume of the metering chamber. Thus, the metering result is subject to inaccuracy.

Advantages of the invention

With the method according to the invention and the device for carrying out the method the metering accuracy when metering very small quantities of fuel for injection is substantially increased. As a result of the fact that the return speed of the metering piston can be kept constant and the switching delay of the solenoid valve can be determined, with the method according to the invention a reference volume is maintained with a high degree of accuracy, which requires a low degree of outlay and for which no separate control devices for setting this volume are necessary. As a result, a reproducible initial setting of the metering piston and an accurate detection of the respective quantity of fuel for injection are obtained at each metering. In particular, fluctuations in metering results due to dynamic influences acting on the metering result as a result of different return speeds of the metering piston are avoided.

According to Patent Claim 2, a metering error at extremely small quantities of fuel for injection is



advantageously reduced in that, in this case, a return of the metering piston is not initiated if a specific travel of the metering piston during the injection process is not exceeded, rather individual injection processes are successively carried out in a cumulative fashion, in which case according to Patent Claim 3 these quantities for injection are detected volumetrically over the travel of the metering piston as the difference between two successive injections.

According to Patent Claim 4, a constant return speed of the metering piston is achieved in a particularly advantageous way in that, in the relief line which relieves the metering chamber, apart from the controlled solenoid valve, a pressure-limiting valve is also provided, the latter being provided according to Patent Claim 6 with a valve element which is subject to the same pressure, as a restoring force, as the metering piston. Thus, using the spring which is provided according to this embodiment, a constant differential pressure can be set at the through-flow area of the relief line so that in this way the quantity discharged from the metering chamber per time unit and thus the return speed of the metering piston can be kept constant.

Further advantageous embodiments of the invention are disclosed in the other subclaims and are explained in greater detail in the description which follows.

#### Drawing

Three exemplary embodiments of the invention are illustrated in the drawing and are explained in greater detail in the description which follows. Figure 1 shows a diagrammatic view of the device according to the invention for carrying out the method according to the invention, Figure 2 shows a graphic view of the profile of the travel of the metering piston against time, with an associated curve of the actuation of the solenoid valve and of the curve of the movement of the valve element, Figure 3 shows the travel of the metering piston against time for a series of very small quantities of fuel for

injection, Figure 4 shows a modified embodiment of the pressure valve according to Figure 1, and Figure 5 shows a second embodiment of the metering device according to Figure 1.

## 5 Description

For metering extremely small quantities of fuel for injection, which are injected by a fuel injection valve 1, such a fuel injection valve 1 is inserted into a metering device 2, which is represented in Figure 1 by a rough diagram. Such a fuel injection valve, which is preferably a high-pressure injection valve which is used in internal combustion engines with autoignition, controls the flow of extremely small quantities of fuel for injection into a metering chamber 3 which is formed in the metering device 2. In the embodiment shown, the metering chamber is an enclosed cylinder 4 in which a metering piston 5 is arranged in a displaceable fashion, the said metering piston 5 bounding the metering chamber 3 with its end side 6 in the cylinder 4. The rear of the metering piston bounds a gas-filled space 7 which is supplied with nitrogen at constant pressure from a nitrogen reservoir container 22. The pressure of the nitrogen gas is adjusted here such that, when fuel is injected into the metering chamber 3, the metering piston 5 can be deflected counter to the restoring force of the nitrogen gas. The movement of the metering piston is detected with a displacement sensor 8 which engages, with a contact pin 9, on the rear of the end side 6 of the metering piston. The fuel injection valve is inserted on a connecting element 10 which leads into the metering chamber 3, and a relief line 11, in which is arranged an electrically controlled valve, for example a solenoid valve 12, which as a 2/2 way valve opens or closes the through-opening of the relief line 12, leads off from the metering chamber 3. In the continuation of the relief line 11 downstream of the solenoid valve 12, a pressure-limiting valve 14 is provided via which the relief line 11 leads without pressure to a fuel discharge. The

pressure-limiting valve has a movable wall in the form of a piston 16 which is guided in a sealed fashion in a hole 17 in the housing 18 of the pressure-limiting valve. The first end side 19 of this piston is adjacent to a pressure chamber 20 in the housing 18 of the pressure-limiting valve, which pressure chamber is connected via a feed line 21 to the same nitrogen reservoir container 22 which also supplies the pressure which is directed to the rear of the metering piston.

10           The other, second end side 24 of the piston 16 bounds an inflow chamber 25 into which a feed line 26 opens parallel to the axis of the hole, the said feed line 26 being continuously connected to the relief line which enters the pressure-limiting valve 14. Opposite the  
15   second end side 24, a discharge port 27 leads off coaxially with respect to the axis of the hole 17, the entry of which discharge port 27 into the inflow chamber 25 is constructed as a valve seat 28. A ball 29 which serves as a valve element and is permanently  
20   anchored in the end side 24 of the piston 16, interacts with the said valve seat 28. In the region of the discharge port, a plunger 31 presses on the said valve element 29, the said plunger 31 being guided in a sealed fashion in the discharge port at its rear end and being  
25   acted on at its rear by a spring 32 which is supported in the housing of the pressure-limiting valve. The rear 33 of the plunger 31 is also connected here to the relief line 11 entering the pressure-limiting valve. On its side opposite the valve element, the plunger bears an  
30   actuation pin 34 which leaves free, between itself and the discharge port, an annular space which is continuously connected to a hole 35 which leads off laterally from the discharge port. This hole 35 leads to the continuing component of the relief line 11 which  
35   feeds the fuel, led off by the pressure-limiting valve, without pressure, to a reservoir container.

With the metering device described, a volume of fuel can be enclosed in the metering chamber 3 using the solenoid valve which closes the relief line 11. The

solenoid valve is in such a position at the start of the metering of small quantities of fuel for injection. In this process, the metering piston 5 assumes an initial position at which it encloses a reference volume of fuel in the metering chamber 3. This initial position is reported back to a control unit 36 via the displacement sensor 8, the said control unit 36 also serving to control the solenoid valve 12. The fuel in the metering chamber 3 is here at a value determined by the pressure of the nitrogen gas-filled space 7. In the example disclosed, fuel is injected via the fuel injection valve 1 into the metering chamber 3 by means of a fuel injection pump. This produces an increase in volume, which consequently leads to a displacement of the metering piston 5, which is in turn detected by the displacement sensor 8. The injection volume is calculated by means of the control device 36 and a connected computer from the difference between this metered volume at the limit position of the metering piston after the injection process and less the reference volume.

In order to set identical conditions for a subsequent metering process, the metering piston is returned to its initial position after the conclusion of the first metering process, at which initial position it again limits the reference volume. This return is carried out by opening the relief line 11 using the solenoid valve 12. The fuel which flows off here flows via the relief line initially to the pressure-limiting valve 14. At the said pressure-limiting valve 14, the valve element 29 is in the closed position, under the effect of the pressure in the pressure chamber 20, which pressure exerts a larger resultant force on the piston 16 than the force which is transmitted to the piston by means of the spring 32. By feeding the fuel into the inflow chamber, the pressure is now additionally applied to the piston 16 on its second end side 24 from the inflow chamber 25, and this pressure also acts on the piston 16 via the rear 23 of the plunger 31. Since the pressure of the fuel flowing into the inflow chamber 25 is also determined by the

pressure in the gas-filled space 7 and on the other hand this same pressure, which prevails in the gas-filled space 7, also acts on the first end side 19 of the piston 16, the piston is force-compensated with respect to the forces acting on it fluidically. However, the force of the spring 33 additionally acts on the piston, the said force now being capable, using the pressure in the inflow chamber 25, of lifting off the valve element 29 from its seat 28 and allowing fuel to flow to the hole 35 or to the continuing relief line 11. If the pressure drops more strongly in the inflow chamber 25 due to an excessively large fuel flow area at the valve seat 28, the closing forces at the piston 16 on the side of the pressure chamber 20 predominate and the discharge area is reduced. With such a valve, it is ensured in this way that a constant pressure difference is obtained at the discharge area between the valve element 29 and the valve seat 28 of the pressure-limiting valve. Due to the quantity of fuel which thus flows off constantly per time unit, it is ensured that the metering piston returns to its initial position at a constant speed.

The end of the return of the metering piston 5 is initiated by closing the solenoid valve 12. This takes place in that, starting from a specific position of the metering piston which is reported by the displacement sensor 8, a control signal is transmitted to the control device 36, by means of which the solenoid valve is in turn actuated. The method of actuation can be seen from the diagrams of Figure 2 discussed below. In this figure, the movement of the metering piston is represented with the curve A. Starting from a level which has been reached, the metering volume MV, corresponding to a limit position of the metering piston after an injection process has taken place, the relief line 11 is opened at a time  $t_1$  and the piston consequently returns to its initial position, the reference volume BV, at an essentially constant speed corresponding to the slope shown, the said initial position being reached at the time  $t_2$ . It remains in this position until, during a new metering

process at the time  $t_3$ , fuel is injected into the metering chamber 3 again. The metering piston is consequently deflected, possibly with a small overshoot process, and then reaches a limit position again, which it maintains until it is returned in the same way to its initial position, before the initiation of a new metering sequence before the relief line is opened.

Curve B represents the opening and closing processes of the solenoid valve 12, which processes are controlled by the voltage profile, shown by the curve C, at the solenoid valve. It can be seen that with the drop of the electric voltage at the solenoid valve at the time  $t_0$  the solenoid valve initially remains in its closed position and does not begin to open until the time  $t_1$ . This time delay between the initiation of the signal and the actual movement of the closing element of the solenoid valve is known and is constant since the movement takes place under the effect of a spring. Fuel cannot flow to the pressure-limiting valve until the actual start of opening. A pulse edge where the voltage supply or current supply of the solenoid valve begins to rise again at the time  $t_1'$  initiates, also after a delay time, the closing movement of the solenoid valve. Only once the time  $t_2$  has been reached, is the said solenoid valve then closed at a time  $t_2$  after the time  $t_1'$ . At this time, the discharge of fuel via the relief line is then also completely suppressed and the metering piston is brought to a standstill. So that the metering piston returns to the desired level BV corresponding to the reference volume, the triggering point of the solenoid valve for the initiation of its closing process must therefore be earlier by the time  $t_2$ . However, a quite specific point in the course of the metering piston 4 corresponds to this time since the metering piston returns at a constant speed. A point in the return movement of the metering piston can now easily be detected as a switching threshold at which the switching delay between the electrical initiation of the closing movement of the solenoid valve and the point at which the

closing actually took place is taken into account. Thus, a very accurate result and a way of reproducing the initial position of the metering piston in a very accurate way are easily obtained.

5           In a metering device described above, very different small quantities of fuel for injection can be detected. When the quantities for injection are very small, e.g. in the region of a fuel pre-injection for internal combustion engines with auto-ignition, this  
10 results in the disadvantage that the size of the metering piston only permits extremely small movement steps as a deflection movement. If returns to the initial position were to take place here, despite the return movement being kept constant and a return speed of the metering  
15 piston which is to be kept corresponding small, certain faults may occur. In such a case, the new device is designed such that the metering piston is only permitted to return to its initial position starting from a specific deflection of the metering piston. Injection  
20 processes of this kind with a very small quantity of fuel for injection then initially take place in a cumulative way until the required deflection of the metering piston is achieved. The metering of these individual quantities for injection can be detected here as a difference of the  
25 position of the metering piston between the individual injection processes. In such a case, the position of the metering piston at the end of the preceding injection then constitutes, in each case, the reference parameter in the form of a reference volume. Such a process is  
30 indicated in Figure 3.

          The movable wall of the pressure-limiting valve 14 is constructed as a piston 16 in the exemplary embodiment given above according to Figure 1. In a modification of this, in another embodiment according to  
35 Figure 4 this movable wall is constructed as a diaphragm 116 which is clamped between a housing component 118a and a housing component 118b of the housing 118 of the pressure-limiting valve, in a sealed fashion. As in the case of the exemplary embodiment according to

Figure 1, the movable wall, now realized as a diaphragm, encloses with its one side 119 the pressure chamber 20, which is already known from the first exemplary embodiment and is connected, as there, to the nitrogen reservoir container 22 via a feed line 21. The second side of the diaphragm closes off the inflow chamber 125 opposite the pressure chamber, into which inflow chamber the feed line 126, which runs parallel to the axis of symmetry of a valve body component 40 which is inserted cylindrically into the housing component 118b and whose end side bounds the inflow chamber 125 at the other end, opens the said feedline 126 being connected at the other end to the relief line component 111a. In addition, a discharge port 127 whose entry into the inflow chamber 125 is constructed as a valve seat 128 is provided in the longitudinal axis of this valve body component as a through-hole. A valve head 41 with a sealing face which extends in a tapering shape interacts with the said valve seat 128 and serves as a valve element, the said valve head 41 being permanently coupled to the diaphragm 116 via a connecting component 42. The valve head merges with a guide shaft 43 which is continuously dipped in the cylindrical hole of the discharge port 127 with a guide piston 44 and forms an annular space 45 between itself and the sealing face of the valve head together with the discharge port 27. The said annular space 45 is continuously connected to a relief line component 111b which branches off from the discharge port in the region of the annular space. The rear 133, facing away from the valve head 41, of the guide piston 44 is connected via the opening, emerging from the valve body component 40, of the discharge port 127 to the relief line component 111a which leads from the solenoid valve 12, and is in turn connected to the inflow chamber 25 via the feed line 126.

This embodiment has the advantage that it is no longer necessary to pay attention to a particular mobility of the piston 16 of the exemplary embodiment according to Figure 1 and to the seal, with respect to the gas cushion, which has to be maintained at the same



tim , since the satisfactory separation of pressure chamber 20 and inflow chamber 125 is ensured using the diaphragm, with a high degree of mobility of the same with a low degree of hysteresis. The guiding of the valve element with the valve head 41 and guide shaft 43 is performed by the discharge port 127 as a guide hole. In this context, because of the low-friction guide, an auxiliary spring, like the spring 32 of the exemplary embodiment according to Figure 1, can also be dispensed with. The mode of operation of this pressure-limiting valve is otherwise the same as that of the first exemplary embodiment according to Figure 1.

In order to obtain a particularly exact metering result, the metering piston 5 of the exemplary embodiment according to Figure 1 must be of particularly lightweight construction and is preferably constructed as a very thin-walled, cup-shaped piston. On the other hand, the metering result is also influenced by friction influences in the guiding of the piston. For this purpose, this guide must be lubricated, which is preferably carried out by means of fuel leaking from the metering chamber. Diesel fuel in particular has lubrication properties in this context. However, to prevent this leaking fuel from penetrating the gas-conducting component, the space 7, it is necessary to provide a leakage groove in the wall of the cylinder which guides the piston. This is shown in Figure 5. Here, the metering piston 105, which is of thin-walled design as illustrated above, again bounds the metering chamber 103 in the cylinder 104 with its end side, fuel being fed into the said metering chamber 103 by a fuel injection valve 101, it being possible for the said fuel to be led off again via the relief line 111 under the control of the electrically controlled valve 112, as in the exemplary embodiment according to Figure 1. The aforesaid leakage groove is positioned as an annular groove 47 in the region of the cylinder 104, which is continuously covered by the thin-walled casing 48 of the metering piston 105 and thus forms an enclosed annular space. This annular space 47 is

connected via the relief line component 211a which comes from the electrically controlled valve 112. This relief line leads out of the annular space 47 at the other end and opens into the pressure-limiting valve 14 or 114 which is merely indicated symbolically in Figure 5. Fuel whose flow is stopped by the electrically controlled valve 112 thus flows through the annular space 47, and the thin-walled casing 48 in the region of this groove is acted on by the pressure of the fuel which corresponds to the nitrogen pressure prevailing in the interior 7. In this way, the thin-walled casing of the piston is prevented from becoming deformed in the region of the annular space 47. Such a deformation would lead to the metering piston failing or at least moving with difficulty. Also, the lubrication of the piston would be adversely affected. With the given solution, leaking fuel can however escape via the annular space 47 so that it leads to a satisfactory separation of the gas component on the one hand and the fuel component on the other. Also, a flow of nitrogen to the annular space 47, which would then occur if the annular space 47 were unpressurized, is preventing from coming about. At least the areas of the piston casing at the lower end at least would then be dried by this flow of nitrogen and thus the displacement property of the piston would be considerably reduced. However, by virtue of this solution according to the invention these disadvantages are overcome.

## Claims

1. Method for metering small quantities of fuel for  
5 injection which are injected into a metering chamber (3)  
by a fuel injection valve during an injection process,  
the increase in volume of the said metering chamber (3)  
being [lacuna] by means of a metering piston (5) which is  
10 moved from its initial position corresponding to a  
reference volume (BV) of the metering chamber counter to  
a constant restoring force into a limit position corre-  
sponding to a metering volume (MV) after the end of the  
injection process, the injection quantity being det r-  
15 mined via the displacement travel of the metering piston  
from the difference between the reference volume and the  
metering volume, and with the re-emptying of the metering  
chamber (3) to the reference volume (BV) after the  
metering process [lacuna] by means of a valve (12) which  
20 is electrically controlled by the movement of the meter-  
ing piston, in a relief line (11) which leads off from  
the metering chamber (3), characterized in that during  
the process of re-emptying the metering chamber (3) an  
essentially constant return speed of the metering pis-  
ton (5) is maintained and a switching signal for the re-  
25 closing of the relief line (11) by the solenoid valve is  
transmitted to the said solenoid valve taking into  
account the switching delay, based in the closing move-  
ment characteristic of the electrically controlled valve,  
including the travel, covered in this period, of th  
30 metering piston at a switching threshold which is posi-  
tioned ahead of the initial position of the metering  
piston.

2. Method according to Claim 1, characterized in  
that the re-emptying of the metering chamber (3) only  
35 takes place after such injection processes or a series of  
injection processes in which in total a specific

adjustment travel of the metering piston from its initial position has been reached.

3. Method according to Claim 2, characterized in that in the case of a series of injection processes which in total have not led to the specific adjustment travel of the metering piston, the position of the metering piston respectively reached after the preceding injection process is used as reference volume for the determination of the injection volume.

4. Metering device for carrying out the method according to Claims 1 to 3 with a metering chamber (3) which is bounded by one end side (6) of a metering piston (5) which can be displaced in a cylinder (4) by fuel injected into the metering chamber (3) counter to a constant restoring force and whose displacement travel is detected by a displacement sensor (8), and with an electrically controlled valve (12) in a relief line (11) which leads off from the metering chamber (3), by means of which valve (12) the relief line (11) is opened after termination of the fuel injection into the metering chamber (3) and when a specific position is reached during the return of the metering piston is closed again when a control signal occurs which is triggered by the said metering piston, characterized in that a pressure-limiting valve (14) is arranged in the relief line in addition to the electrically controlled valve.

5. Metering device according to Claim 4, characterized in that the pressure-limiting valve lies downstream of the solenoid valve (12).

6. Metering device according to Claim 4 or 5, characterized in that the metering piston (5) is acted on by a constant fluid pressure and the pressure-limiting valve (14) has an adjustable wall (16) which is acted on on the one, first side (19) by the constant fluid pressure and on the other, second side (24) by the pressure in the relief line (11) downstream of the electrically controlled valve (12) and by the force of a spring (32), by means of which spring, with the cooperation of the pressure on the second end side (24), a valve

element (29) which can be adjusted with the movable wall (16) can be moved out of its closed position.

7. Metering device according to Claim 6, characterized in that the movable wall is a cylindrical piston (16) which is guided in the housing (18) of the pressure-limiting valve (14) and which bounds, with its second side (24), an inflow chamber (25) which is connected to the relief line lying upstream of the pressure control valve, and the valve element (29) is connected to the second side (24) of the piston (16) and, projecting into the inflow chamber, interacts with a valve seat (28) provided on a discharge port (27) which opens in there.

8. Metering device according to Claim 7, characterized in that the spring (32) which loads the piston (16) acts on the piston (16) via a plunger (31) which is guided in an extension of the discharge port (27).

9. Metering arrangement according to Claim 8, characterized in that the rear of the plunger is also subject to the pressure in the relief line (11) upstream of the pressure-limiting valve (14).

10. Metering device according to Claim 9, characterized in that a ball which is pressed into the piston (16) is provided as a valve element.

11. Metering device according to Claim 6, characterized in that the movable wall is a diaphragm (116) which is clamped in the housing (118a, 118b) of the pressure-limiting valve (114) and bounds with its second side (124) an inflow chamber (125) which is connected to the component, lying upstream of the pressure control valve (114), of the relief line (111a), and the valve element (129) is connected to the second side (124) of the diaphragm (116) and, projecting into the inflow chamber (125), interacts with a valve seat (128) provided on a discharge port (127) which opens in there.

12. Metering device according to Claim 11, characterized in that the valve element (129) has a valve head (41) which is provided with a guide shaft (43), the guide shaft (43) having adjacent to the valve head an annular groove which is bounded at the other end by a

guide piston (44) of the guide shaft (43) and forms with the discharge port an annular space (45) which is continuously connected to a component, leading off from the inner wall of the discharge port, of the relief line (111b), and the valve head (41) is coupled to the diaphragm (116) with a connecting component (42) and controls the discharge port with its sealing face.

13. Metering device according to Claim 12, characterized in that the rear (133), facing away from the valve head (41), of the guide shaft (43) is also subject to the pressure in the relief line component (111a) upstream of the pressure-limiting valve.

14. Metering device according to Claim 6, characterized in that the metering piston (105) is a piston which is of cup-shaped construction and is provided with a thin peripheral wall (48) and whose outwardly pointing base bounds, as an end side, the metering chamber (103) and the displacement sensor (8) is coupled in a frictionally engaging way to the inner cup floor of the said piston and is acted on by the fluid pressure.

15. Metering device according to Claim 14, characterized in that an annular groove (47) is arranged in the wall of the cylinder (104) in which the metering piston (105) is guided, the said annular groove (47) forming together with the metering piston (105) an annular space which is continuously connected to the relief line component (211a) which lies downstream of the electrically controlled valve (12).

16. Metering device according to Claim 15, characterized in that the annular space (47) is located in the relief line component (211a) between the electrically controlled valve (112) and the pressure-limiting valve (14, 114).

17. A metering device substantially as herein described with reference to Figures 1, 2 and 3, or Figure 4, or Figure 5 of the accompanying drawings.

Examiner's report to the Comptroller under Section 17  
(The Search report)

Application number  
GB 9518870.2

**Relevant Technical Fields**

- (i) UK Cl (Ed.N) F1B, G1RRCT  
(ii) Int Cl (Ed.6) F02M 65/00, G01F 3/16

Search Examiner  
R J DENNIS

Date of completion of Search  
14 NOVEMBER 1995

**Databases** (see below)

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

Documents considered relevant following a search in respect of Claims :-  
1 TO 17

(ii)

**Categories of documents**

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| <p><b>X:</b> Document indicating lack of novelty or of inventive step.</p> <p><b>Y:</b> Document indicating lack of inventive step if combined with one or more other documents of the same category.</p> <p><b>A:</b> Document indicating technological background and/or state of the art.</p> | <p><b>P:</b> Document published on or after the declared priority date but before the filing date of the present application.</p> <p><b>E:</b> Patent document published on or after, but with priority date earlier than, the filing date of the present application.</p> <p><b>&amp;:</b> Member of the same patent family; corresponding document.</p> |
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Category	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2233101 A (DAIMLER)	1
A	GB 2204702 A (TOYOTA)	1
A	GB 2105407 A (HARTRIDGE)	1
X	WO 93/08401 A1 (LUCAS)	1 at least

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

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